STRUCTURAL EVOLUTION: THE EFFECT OF ORGANIZATION SIZE ON COMPLEXITY ACROSS TIME

Edward Moore

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THESIS

STRUCTURAL EVOLUTION: THE EFFECT OF
ORGANIZATION SIZE ON COMPLEXITY ACROSS TIME

by

Edward Moore, Jr.

June 1974

Thesis Advisor: W. J. Haga

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T161530

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Structural Evolution: The Effect of Organization Size on Complexity Across Time		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis; June 1974
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Edward Moore, Jr.		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		12. REPORT DATE June 1974
		13. NUMBER OF PAGES 47
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Naval Postgraduate School Monterey, California 93940		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

p coefficient
Harmonic Series Model
organization size
organization complexity

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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(Page 1) S/N 0102-014-6601 |

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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Structural Evolution: The Effect of Organization Size on Complexity Across Time

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MASTER OF SCIENCE IN MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL
June 1974

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ABSTRACT

Sixty-eight years in the evolution of a formal organization were studied to determine the effects of organizational size on organizational complexity across time. The Kolmogorov-Smirnov statistic was used to test whether an expected rank-frequency distribution of roles, generated by the Mayhew-James-Childers Harmonic Series predicted observed rank-frequency distribution of roles. The Harmonic Series Model was of less utility in predicting organization shape than expected. The Kolmogorov-Smirnov statistic was more appropriate than the Chi-square in testing this model, however, it was unstable for organizations sizes in this sample below 25. It did not render a clear pattern testing the harmonic series with data from this sample. A more generalized alternative version of the Harmonic Series Model is suggested.

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I. INTRODUCTION

A. BACKGROUND

Empirical studies of formal dimensions of organization structure have sought to discover patterns of association between factors that lead to increases in organization complexity (Blau and Schoenerr, 1973; Blauner, 1964; Child, 1973; Hickson, et al., 1969; Samuel and Mannheim, 1970; Woodward, 1965). These investigations have attempted to develop a set of hypotheses that are sufficiently generalizable to become the basis for constructing formal theories of organization. Each of these studies has used sample organizations of varying size, purpose, technology, and location to identify causal factors leading to changes in complexity.

Two formal variables that have been examined extensively in the literature are organization size and complexity, or structural differentiation. The data from which causal inferences relating these two variables to structure have been constructed have come largely from cross-sectional research designs. While these designs have been useful in dealing with rival hypotheses and in establishing covariance, cross-sectional designs make arbitrary assumptions about the time ordering of variables. Longitudinal data collection designs are necessary to analyze the causal relationship of organization size to complexity by accounting for time order of these elements.

In a study of the administrative structures of 194 departments of finance in city, county, and state governments, Meyer (1972) compared survey data collected in 1966 with data collected in a restudy in 1971

of the same organizations. Hendershot and James (1972) used Office of Education data on 299 school districts collected at two points in time. Haire (1959) examined case histories of four organizations in a longitudinal study of growth at five points in time. However, organization structure has not been studied in a research design spanning several years in a continuous series.

B. LITERATURE ON THE CHARACTERISTICS OF BUREAUCRACIES

1. Cross-Sectional Studies of Size and Structural Differentiation

According to Hall (1967), relationships between organization size and other structural components are inconsistent in that neither complexity nor formalization can be predicted from knowledge of organization size. He suggested that size may be irrelevant as a factor in determining structural differentiation.

Klatzky (1970) proposed two models to explain the relationship between the size of an organization and the percentage of its staff personnel. In his regression model, Klatzky's results indicate that the effect of size is partially dependent on the level of complexity in an organization. In his logarithmic model increasing size decreases the staff component at a decreasing rate, explaining slightly more variance than the regression model. However, Klatzky rejected the logarithmic model in favor of the regression model. He reasoned that although the logarithmic model provided a slightly better fit to his data, it had less theoretical basis than the regression model and, therefore, was unable to explain the social processes involved.

Blau (1970) and Blau and Schoenherr (1971) analyzed the effects of a variety of formal characteristics of structure across 53 employment security agencies, along with parallel analyses of the same characteristics

among 387 component divisions and 1201 local offices of these agencies. Their results indicated that size had a positive relationship to differentiation and administrative overhead. Thus, the larger an organization and the scope of its responsibilities, the more pronounced will be its structural differentiation. The same outcome was found among the agencies' subunits. Blau and Schoenherr reason, however, that large organizations have a greater structural division of labor; greater size was related to more and larger structural components. As organization size becomes larger, it generates structural differentiation, and thus, only indirectly raises administrative overhead. On the other hand, the administrative ratio decreases with increases in organizational size despite the increase in the administrative ratio resulting from differentiation in large organizations. They concluded that the relationship between size and other structural variables is nonlinear.

A departure from the Weberian concept of bureaucracy has been pursued by Pugh, et al., (1968 and 1969). Their Aston group's multidimensional approach suggested a need for only four orthogonal dimensions to describe the structure of any work organization. These have been defined as (a) structuring of activities, which encompasses specialization, standardization, formalization and vertical span; (b) concentration of authority, encompassing centralization, percentage of line managers, and standardization of personnel procedures; (c) line control of work flow; and (d) relative size of supportive component. Pugh and his associates argued that the independence of these first two dimensions implies that Weber's association of structuring with decentralization is no longer useful for describing organizational processes. They further contend (1969) that interactions among independent structural elements allow organizations to bureaucratize along several dimensions.

Child's (1972) replication of the Aston study confirmed an association between specialization, standardization of procedures, vertical span, and formalization expressed by the structuring of activities concept. However, centralization of decision making was found to be negatively related to structuring in a way that conformed closely to Weber's (1946) description of the bureaucratic mode of administrative control.

Later, Child (1973) compared size-complexity regressions across different industries using data previously compiled by other investigators in five studies. He found that size, in conjunction with technology, location, and environmental variables, predicted organization complexity. However, the degree of complexity had a more direct relationship with formalization of procedures than it did with size. Further, complexity was a critical factor in understanding organization structure but was not more significant than size as a determining factor.

Reimann (1973) supported the Aston group's multidimensional approach to organization structure. In a factor analysis of data from 19 U.S. manufacturing firms in connection with the structural scales developed by Pugh, et al. (1968) Reimann found three independent dimensions of structure: decentralization, specialization, and formalization. A variety of structural arrangements appeared to be equally viable for the 19 sampled organizations.

However, Mansfield (1973) reviewed the Aston group's methodology and concluded that the main variables in their research were scalar quantities, not vector quantities, as they had suggested. Mansfield defined vector quantities as those consisting of magnitude and direction. Scalar quantities were composed of magnitude only. Pugh's measures of

organizational structure were additive scalar quantities. His tests of whether these measures formed scaleable dimensions was pointless, since showing that they were scaleable dimensions was not necessary to justify the addition of the item scores obtained for these dimensions. Thus, in re-evaluating Pugh's data, the direct relationship between bureaucratization and centralization of decision making was found to be weak. However, size affected both of these variables. Large bureaucratic organizations were more likely to have decentralized decision making than small nonbureaucratic ones. Increasing size appeared to compel managers to govern behavior with rules in order to reduce the range of day to day problems they confronted. Pugh's conclusion that the bureaucratic ideal type was no longer useful may have been premature. Standardization and formalization were found to be associated with other structural variables in a way that was compatible with Weber's reasoning.

2. <u>Longitudinal Studies Involving Size and Structural Differentiation</u>

Haire (1959) used case histories from four industrial firms to support a biological model that related size and complexity in the regulation and description of organizational growth. He applied the square-cube law which postulates that, in normal spatial geometry, as volume increases by a cube function, the surface enclosing it increases by only a square. Haire hypothesized that as an organization grows, the internal structure needed to support internal coordination grows faster than overall size, eventually consuming a disproportion of a firm's productive capacity. Thus, disproportionate structural growth across time in these functional areas resulted from survival oriented resistance to internally generated forces tending to destroy the organization. His results indicated that the percentage of staff increased with size, up to some point, and then stabilized.

Hendershot and James (1972), using data from U.S. school districts at two points in time, found a general negative relationship between size and the administration-production ratio. Additionally, differences in recent histories of growth may confound comparisons of administration-production ratios in organizations of different sizes, as it does for school districts.

In a study using path analytic techniques on city, county, and state departments of finance in 1966 and 1971, Meyer (1972) found the effects of size on number of subunits, levels of hierarchy, and number of supervisors to be ubiquitous. Causality was unidirectional; other parameters of organizations had almost no affect on size. The effects of size were greatest on parameters which managers could most easily manipulate. Additionally, apparent relationships among parameters other than size vanished when size was controlled for as an influencing variable.

3. The Harmonic Series Model

Mayhew, et al. (1972) drew from Zipf's general theory of social organization (1949) to derive a prediction of the distribution of employees in organization roles. When other variables affecting structural differentiation were held constant, Blau's (1970) proposition, that complexity is an increasing function of size at declining rates, might be generated by computing expected size of each role with a harmonic series.

4. Summary of the Literature

Predictions from cross-sectional studies about the causal relationship of size and complexity as two dimensions of organization shape have been conflicting. For example, using the Weberian approach, Blau and Schoenherr found that complexity increased at declining rates with increases in size. Yet, another researcher observed that complexity

cannot be implied from knowledge of an organization's size (Hall, 1967). Still another postulated that the effect of size is dependent on the level of complexity (Klatzky, 1970).

Studies by the Aston group, using their multidimensional approach, concluded that organizations may become bureaucratic in a variety of ways. Thus, size and complexity move together, but are subsumed in the context of an organization which, along with other variables, determine organization shape. Another study, using cross-sectional data, confirmed the Aston group's finding that size predicted complexity, but concluded that complexity interacts more with formalization than size to predict structure (Child, 1973). Mansfield (1973) has suggested that the Aston group interpreted the measurements of their main variables incorrectly. Scalar quantities were discussed as if they were vector quantities, thus limiting the predictive power of the Aston group's multidimensional approach.

Longitudinal studies have also drawn different conclusions from empirical data about the effects of size and complexity on structure. One study concluded that as size increased over time, complexity increased in the form of a disproportion of resources allocated to staff and clerical positions for internal control, coordination, and communication (Haire, 1959). Another study suggested a negative relationship between size, growth, and the administration-production ratio (Hendershot and James, 1972). Yet another found the effect of size on other structural variables to be pervasive (Meyer, 1972). The reason underlying different interpretations of the empirical data may be found in the different analytic techniques applied to the data, and the research designs themselves.

The structural determinants of organizations have been treated in the literature primarily at one or two points in time. Size and complexity have not been considered in terms of process. To the extent that size and complexity interact with each other and other structural variables across time, the analysis of data spanning a continuous period of time should refine empirical insights.

This study investigated the Harmonic Series Model developed by Mayhew, et al., (1972) from data reported in Childers, et al. (1971). The data in the present study was gathered from archival records of a California Unified School District and its County Office of Education. The objective of the study was to record, analyze, and document the interaction of size and complexity across time. How the study accomplished these objectives is described in the next chapter.

II. METHODOLOGY

A. THE SAMPLE

The data for this study was gathered from a California Unified School District, hereafter called the Central Coast Unified School District. The district was established in 1896, and through fiscal year 1945 operated as two school systems, one for elementary grades and the other for a high school. A single Board of School Trustees composed of three elected resident citizens presided over both systems. The Clerk of the Board, one of the elected members, maintained separate financial records and minutes of Board meetings for each of the two districts. Unification of the two districts in fiscal year 1946 resulted in consolidated record keeping. In 1946 the Board membership was also enlarged to five elected residents of the town.

Unified School Districts in California operate under state law, with some financial supervision at the county level, but are basically autonomous in their management. Unified districts differ from other California school districts in that they must contain at least four elementary schools. In addition, at least one high school must be located in the general geographical area of the four elementary schools (California Education Code, 1972).

Central Coast Unified School District was the subject of an earlier study, not related to the present endeavor, by the investigator's principal Thesis advisor. As a result of the previous study, the advisor's acquaintance with one of the district's senior staff members permitted access to the data used in this study.

B. DESIGN OF DATA COLLECTION

Minutes of the district's Board of School Trustees, dating from fiscal year 1904 through 1962 provided most of the data on structure for those years. Accompanying financial records for the fiscal years 1904 through 1911 and 1917 through 1922 were also obtained. School district telephone directories listing all school employees by position from fiscal year 1959 through 1974 were used to develop organization charts for these years. Surviving copies of a document entitled "Principal's October Report" were used to refine high school structure and roles, and to cross reference the available financial records on teachers and administrators salaries for fiscal years 1915 and 1916, 1918 through 1927, and 1929 through 1974. With the permission of the County Superintendent of Education and the cooperation of the Assistant County Superintendent of Education for Business, annual district reports to the state summarizing Average Daily Attendance, total receipts and expenditures, capital

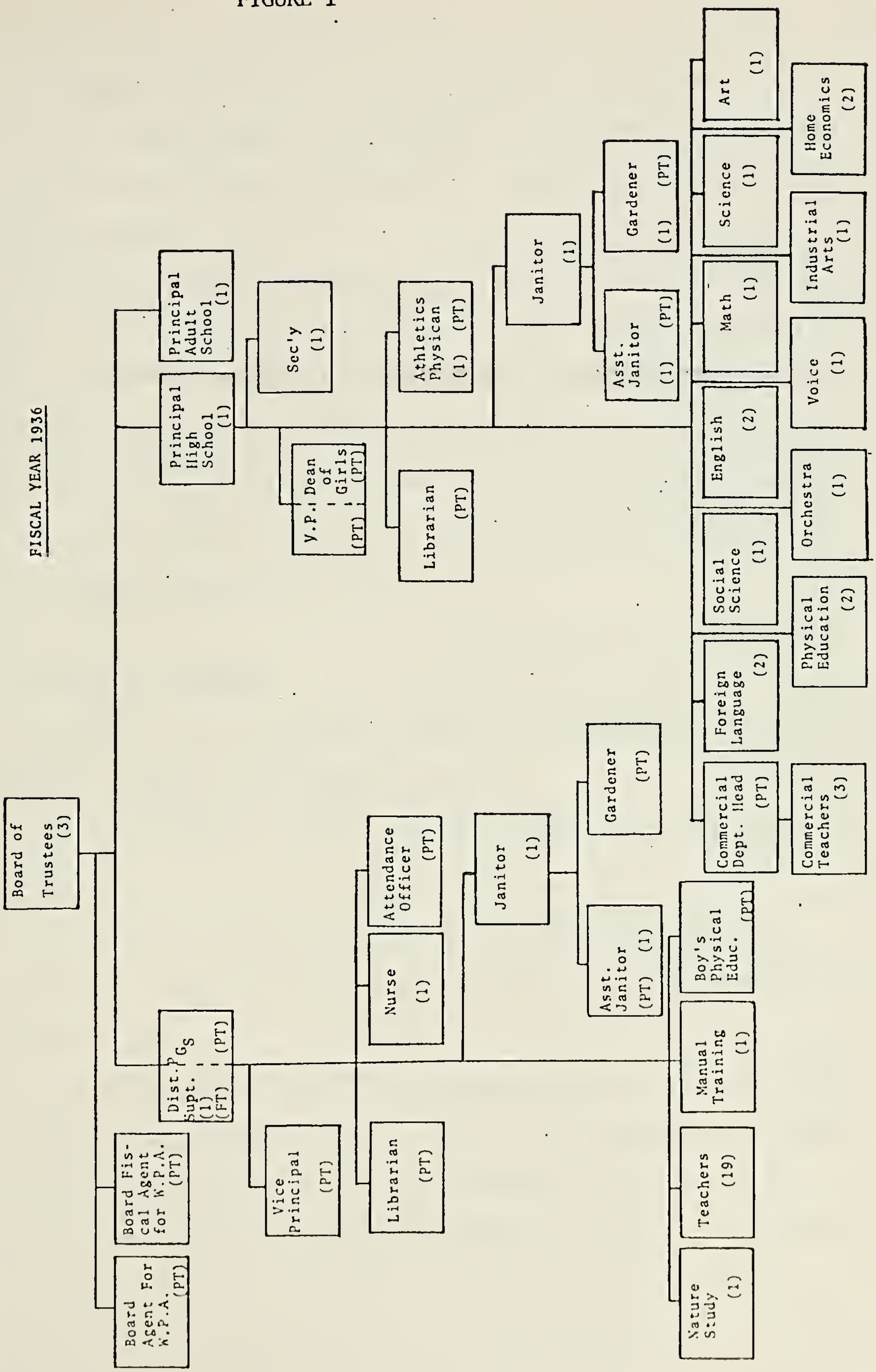
outlay, total teachers salaries, and total administrators salaries, were reviewed. These provided further data for fiscal year 1904 through 1974. In addition, these reports listed the number of administrators by category, supervising and non-supervising, and total number of elementary and high school teachers for fiscal year 1904 through 1938.

The former high school Principal from fiscal year 1952 through fiscal year 1972, was contacted to clarify apparent discrepancies in the data for those years. Moreover, the high school Principal from fiscal year 1921 through 1948, through written interrogatories, provided additional structural information for the years spanning his tenure. Three fiscal years, 1956 through 1958, were excluded from the sample because of the lack of reliable information concerning the number of high school roles in existence and teachers employed during this period.

Data analysis began with construction of an organization chart for each fiscal year, 1904 through 1974. California law requires each school district to dissolve and re-form each July (California Education Code, 1972). The Board of Trustees usually conducted hire-rehire interviews for all school employees during May and June of each year. However, the Board attempted to fill all new or vacated, formally defined, positions whenever the situation arose during the year. Thus, the records of monthly meetings and special meetings of the Board for the 59 available years were used to ascertain necessary modifications to the organization charts. Part-time and full-time positions were differentiated. Figure 1 shows a chart from a single year.

A list of all positions was prepared for each year indicating the number of people in each occupation on either a full-time or a part-time basis. Individuals could hold full-time and part-time positions

FIGURE 1


FISCAL YEAR 1936
Board of Trustees (3)
Board Agent For W.P.A. (PT)
Board Fiscal Agent for W.P.A. (PT)
Dist. Supt. (1) (FT) | P.G.S (PT)
Vice Principal (PT)
Librarian (PT)
Nurse (1)
Attendance Officer (PT)
Janitor (1)
Asst. Janitor (PT) (1)
Gardener (PT)
Nature Study (1)
Teachers (19)
Manual Training (1)
Boy's Physical Educ. (PT)
Principal High School (1)
Principal Adult School (1)
Sec'y (1)
V.P. (PT) | Dean of Girls (PT)
Librarian (PT)
Athletics Physican (1) (PT)
Janitor (1)
Asst. Janitor (1) (PT)
Gardener (1) (PT)
Commercial Dept. Head (PT)
Commercial Teachers (3)
Foreign Language (2)
Physical Education (2)
Social Science (1)
Orchestra (1)
English (2)
Voice (1)
Math (1)
Industrial Arts (1)
Science (1)
Home Economics (2)
Art (1)

simultaneously, e.g., full-time teacher and part-time librarian. That individual would be counted as one employee in two roles: one full-time and one part-time. By definition, no individual held more than one full-time position. This study is limited to an analysis of full-time positions.

Roles were ranked according to the number of people in each occupation. For example, the role with the largest number of occupants was ranked one, the role with the next largest number of occupants was ranked two, and so on. Ties were ranked in arbitrary sequence. The resulting distribution constituted the observed rank-frequency distribution of roles. Appendix A and B demonstrate how Figure 1 was coded using these decision rules.

C. ANALYSIS STRATEGY

Mayhew, et al. (1972) have defined the occupational structure of a formal organization mathematically as:

n = the number of different occupational roles in the formal system;

S = the size (number of employees) of the formal system;

f = the number (frequency) of employees in the r^{th} occupational role;

r_i = the rank of the i^{th} occupational category (role) according to decreasing values of f_i (r_1 is the rank of the largest category, r_2 is the rank of the next largest category, etc.);

F = the number (frequency) of employees in the largest category ($F = f_1$);

p = the ratio of the force of unification to the force of diversification; where

$$F = n^p \qquad (1)$$

Thus, having determined F and n from the organization charts, the value of p was calculated for each year using

$$p = \frac{\log F}{\log n} \qquad (2)$$

Expected rank-frequency distributions of roles for the observed F, (f_1), were generated for each year on an IBM 360 computer employing an algorithm developed from the generalized harmonic series discussed by Mayhew, et al. (1972).

To test the strength of association between the two distributions, Pearson zero-order product-moment correlations of actual versus expected rank-frequency distributions were also computed for a sample drawn from the entire sample of 68 years.

The Chi-square statistic was deemed inappropriate as a test of the degree of independence of the observed from the expected distribution. Chi-square gives the most accurate results when the value in each cell, expected and observed, is large (Blalock, 1960). Most of the values for the sample were small. In many cases less than five employees were recorded in the majority of roles for each year. Applying a constant correction factor to each cell as recommended by Nie, et al. (1970), was inappropriate because it would have distorted both distributions, and generated somewhat smaller values of Chi-square.

Additionally, the Statistical Package for the Social Sciences, (SPSS), on the IBM 360 computer at the Naval Postgraduate School would

not accept the expected values generated by the harmonic series algorithm for comparison with the actual frequency distribution of roles. The SPSS program, as required by the logic of Chi-square (Siegel, 1956; Blalock, 1960; and Nie, et. al., 1970), generated its own expected values for comparison with the observed distribution. This confounding feature of packaged Chi-square programs, together with the curvilinearity of the distributions, led to the abandonment of Chi-square as a test of the goodness of fit of the Harmonic Series Model.

Kim and Jennrich's application of the exact sampling distribution of the two sample Kolmogorov-Smirnov Criterion,

$$D_{mn}, \quad m \leq n$$

for nonlinear distributions with sample sizes less than 100 was used to compare the theoretical with the observed rank-frequency distributions (Harter and Owen, 1970). This test sequentially computed the maximum vertical difference between the two distributions. A statistically significant difference (prob. $\leq$ .05) between the two distributions at any point was evidence that the two samples were not drawn from a common distribution.

Using the parametric t-test, the power-efficiency of the Kolmogorov-Smirnov test has been rated at 96 percent for small samples by Siegel (1956). However, when the size and number of intervals in the samples are very small, the maximum vertical deviation of the two distributions may be obscured, resulting in spurious decisions about the null hypothesis. The data in this study contained several years for which the size and number of intervals were small. These were compared with years in which the size-interval limitation did not apply, to determine whether it was operative in this sample.

III. EMPIRICAL FINDINGS

Analysis of the size and complexity data revealed significant differences between the actual and expected rank-frequency distribution of roles. However, these differences did not show a clear pattern across time.

A. THE p COEFFICIENT AND ORGANIZATION SIZE ACROSS TIME

The computation of p coefficients for this organization revealed that the coefficients exceeded unity in 40 of the 68 sample years. The coefficients were less than or equal to unity for the remaining 28 years. A plot of the p coefficients revealed no consistent pattern across time in terms of absolute increases or decreases. However, during the early years of this organization's life, 1904 through 1932, p coefficients were, generally, less than or equal to unity. For later years, 1933 through 1974, p coefficients tended to be greater than unity.

The data in Table I also indicated that p increased at a decreasing rate up to an organization size of 160 employees. It decreased at a decreasing rate for sizes beyond 160 employees.

TABLE I

p Coefficients across Time and Organization Size

Fiscal Year	p Coefficient for Full-time F and n	Organization Size (Full-time Employees)
1904	.8982	10
1905	1.0860	12
1906	.8857	12
1907	.9464	13
1908	1.0000	14
1909	1.0000	14
1910	.9464	13
1911	.8106	16
1912	1.0000	14
1913	1.0480	19
1914	.9163	19
1915	.9163	19
1916	.8368	20
1917	.8368	20
1918	.8842	19
1919	.8842	19
1920	.9266	20
1921	.8977	22
1922	1.0000	23
1923	1.0321	26
1924	.9471	28
1925	1.0000	30

Fiscal Year	p Coefficient for Full-time F and n	Organization Size (Full-time Employees)
1926	1.0000	30
1927	1.1061	37
1928	1.1631	34
1929	1.0673	37
1930	.9801	39
1931	1.0173	43
1932	1.0173	43
1933	1.0339	43
1934	.9816	41
1935	.9255	40
1936	1.0000	44
1937	1.0340	44
1938	1.0497	49
1939	1.0694	49
1940	1.0694	49
1941	1.0848	51
1942	1.0339	51
1943	1.0174	47
1944	1.0000	48
1945	1.0339	48
1946	1.0847	60
1947	1.0128	59
1948	1.1362	74
1949	1.1046	74
1950	1.1537	83

Fiscal Year	p Coefficient for Full-time F and n	Organization Size (Full-time Employees)
1951	1.0754	84
1952	1.1267	88
1953	1.1423	97
1954	1.0972	112
1955	1.1676	114
1959	1.0623	162
1960	1.0906	189
1961	1.0972	200
1962	1.1300	190
1963	1.0604	227
1964	1.0445	234
1965	1.0670	245
1966	1.0725	263
1967	1.0180	257
1968	1.0249	260
1969	1.0362	300
1970	1.0362	283
1971	1.0076	285
1972	.9792	281
1973	.9180	292
1974	.8853	290

B. CORRELATION COEFFICIENTS FOR OBSERVED VERSUS EXPECTED RANK-FREQUENCY DISTRIBUTIONS

Pearson zero-order product-moment correlation of the actual versus the theoretical rank-frequency distributions for selected years appear in Table II. The results indicate a strong association between these two distributions throughout the range of total number of roles and F for the years sampled.

C. THE KOLMOGOROV-SMIRNOV TWO-SAMPLE EXACT TEST

The null hypothesis was that the observed rank-frequency was the same distribution of roles as the expected rank-frequency distribution of roles. Year by year analysis of the distributions, using the Kolmogorov-Smirnov two-sample exact test, as modified by Kim and Jennrich for sample sizes less than 100, revealed some statistically significant differences between them at the .05 and some at the .01 significance levels.

In 48 of the 68 years examined, the Kolmogorov-Smirnov test rejected, at the .05 level, the hypothesis that the Harmonic Series predicted the observed rank-frequency distribution of roles (Table III). The rejection pattern, however, was inconsistent across time. The Kolmogorov-Smirnov test was unstable for very small sample sizes with few intervals between values. However, when the years for which 25 or fewer roles per distribution occurred were excluded from consideration, the Harmonic Series distributions, as predictor of the observed distributions, were rejected in 14 of the remaining 23 years. The pattern of rejection, however, remained inconsistent across time.

TABLE II

Pearson Product-Moment Correlations of Observed Versus Expected Role Rank-Frequency Distributions for Selected Years

Fiscal Year	Number Roles	F	Correlation Coefficient	Probability
1905	6	7	.9312	.003
1914	9	9	.9295	.001
1929	15	18	.9202	.001
1935	20	16	.8990	.001
1942	18	21	.9240	.001
1955	29	41	.9562	.001
1963	49	62	.9672	.001
1968	65	71	.9576	.001
1971	62	64	.9810	.001

TABLE III

Two-Sample Test Using the Kolmogorov-Smirnov Criterion on Observed versus Expected Rank-Frequency Distribution of Roles

Fiscal Year	Kolmogorov Criterion	Prob. of Kolmogorov Criterion Exceeding c	Total Number Full-time Roles	Value of F	Value of p
1904	.6667	.1429	6	5	.8982
1905	.6667	.1429	6	7	1.0860
1906	.8333	.0260	9	7	.8857
1907	.8333	.0260	9	8	.9464
1908	.8333	.0260	9	9	1.0000
1909	.8333	.0260	9	9	1.0000
1910	.8333	.0260	9	8	.9464
1911	.8889	.0007	13	8	.8106
1912	.8571	.0082	9	9	1.0000
1913	.6667	.0336	9	10	1.0480
1914	.7778	.0063	11	9	.9163
1915	.8000	.0021	11	9	.9163
1916	.8000	.0021	12	8	.8368
1917	.8182	.0007	12	8	.8368
1918	.8000	.0021	12	9	.8842
1919	.8000	.0021	12	9	.8842
1920	.8000	.0021	12	10	.9266
1921	.7273	.0044	13	10	.8977
1922	.8000	.0021	12	12	1.0000
1923	.6923	.0029	12	13	1.0321

Fiscal Year	Kolmogorov Criterion	Prob. of Kolmogorov Criterion Exceeding c	Total Number Full-time Roles	Value of F	Value of p
1924	.8000	.0004	15	13	.9471
1925	.8000	.0004	15	15	1.0000
1926	.8000	.0004	15	15	1.0000
1927	.7857	.0002	15	20	1.1061
1928	.4167	.2558	12	18	1.1631
1929	.5333	.0262	15	18	1.0673
1930	.6111	.0018	18	17	.9801
1931	.6316	.0007	19	20	1.0173
1932	.5789	.0028	19	20	1.0173
1933	.6842	.0007	19	21	1.0339
1934	.6000	.0011	19	18	.9816
1935	.6500	.0003	20	16	.9255
1936	.6250	.0003	19	19	1.0000
1937	.4737	.0267	19	21	1.0340
1938	.4444	.0560	19	22	1.0497
1939	.4706	.0450	18	22	1.0694
1940	.5000	.0207	18	22	1.0694
1941	.4118	.1124	18	23	1.0848
1942	.2778	.1324	19	21	1.0339
1943	.3889	.1324	19	20	1.0174
1944	.4375	.0933	21	21	1.0000
1945	.4118	.1124	19	21	1.0339
1946	.4444	.0560	23	30	1.0847
1947	.4091	.0493	24	25	1.0128

Fiscal Year	Kolmogorov Criterion	Prob. of Kolmogorov Criterion Exceeding c	Total Number Full-time Roles	Value of F	Value of p
1948	.3000	.1745	24	37	1.1362
1949	.3500	.1745	25	35	1.1046
1950	.3000	.1745	25	41	1.1537
1951	.3478	.1243	28	36	1.0754
1952	.4400	.0148	27	41	1.1267
1953	.5333	.0010	28	45	1.1423
1954	.3704	.0500	36	51	1.0972
1955	.3448	.1000	29	41	1.1676
1959	.2821	.1000	39	49	1.0623
1960	.3409	.0250	44	62	1.0906
1961	.3023	.0500	43	62	1.0972
1962	.2632	.0250	38	61	1.1300
1963	.2857	.0250	49	62	1.0604
1964	.3077	.0010	52	62	1.0445
1965	.3200	.0010	50	65	1.0670
1966	.3750	.0010	56	75	1.0725
1967	.4219	.0010	64	69	1.0180
1968	.4462	.0050	64	71	1.0249
1969	.4032	.0010	62	72	1.0362
1970	.3509	.0010	57	66	1.0362
1971	.3710	.0010	62	64	1.0076
1972	.3770	.0010	61	56	.9792
1973	.4054	.0010	74	52	.9180
1974	.3571	.0010	70	43	.8853

A more rigorous test of the null hypothesis using the .01 significance level as the decision point, showed that the Kolmogorov-Smirnov test rejected the Harmonic Series predictions of the observed rank-frequency role distribution in 33 of the 68 years examined (Table III). Limiting the test to those years in which the distributions contained 25 or more roles indicated that the Harmonic Series Model failed to predict the observed rank-frequency distribution of roles for 10 of the 23 years involved. In both instances the accept-reject pattern was inconsistent across time. In addition, the rejection of the null hypothesis did not vary consistently with total number of full-time roles, F, or the p coefficient.

IV. INTERPRETATION OF THE FINDINGS

The purpose of this study was to examine the effect of organization size on complexity in a bureaucratic organization. Both variables were examined, not from the perspective of a static, cross-sectional data set, but as a process that unfolded across time.

A. THE p COEFFICIENT AND ORGANIZATION SIZE ACROSS TIME

An examination of the Mayhew, et al. p coefficient across time revealed that it exceeded unity in 40 of the 68 years studied. The absolute variations in these coefficients displayed no consistent pattern across time. However, the coefficients were generally less than or equal to unity when the organization was young, and consistently greater than unity as the organization became bureaucratized. These findings are inconsistent with the Mayhew, et al. (1972) expectation that

$$\lim_{S \to \infty} p = 1 , \qquad (3)$$

and that the limit is approached from below. Their rationale was that smaller organizations would be more likely to have personnel shortages than larger organizations, and hence, p values would be less than unity. The findings of this study indicate that p values may exceed unity. Further, since a specific p value for any size organization is dependent on the size of the role with the largest number of people, F, and the total number of different occupational roles, n, that p value will exceed unity when the force of diversification is greater than the force of unification.

The findings also indicate that p increased at a decreasing rate up to 160 employees, then decreased at a decreasing rate up to 300 employees. In part, this finding contradicts Mayhew's (1972) hypothesis that p increases at a decreasing rate over the range of the size of an organization. Mayhew assumed that U.S. military organizations, upon which he based his findings, experience personnel shortages because they compete less favorably for available personnel with private industry. Clearly, this assumption limits his hypothesis's generalizability to other organizational contexts. U.S. military organizations are not representative of the broad range of organizations found in an industrial society let alone the rest of the world. An alternative interpretation suggested by the findings of this study is that, over the life cycle of an organization, p increases at a decreasing rate with increases in size as an organization bureaucratizes, then decreases at a decreasing rate with increases in size once bureaucratization has stabilized.

B. CORRELATION COEFFICIENTS FOR OBSERVED VERSUS EXPECTED RANK-FREQUENCY DISTRIBUTIONS

The results here indicated that, for the years selected, a strong association existed between the two distributions. It is expected

that the association between the distributions for the intervening years would also be strong.

The correlation coefficients measured the amount of spread about the linear least squares equation. Representing F on the x-axis and r_n on the y-axis, the two curvilinear distributions were treated as if they were linear, a line was fitted through each and the spread about the lines were compared. This procedure, while appropriate for essentially linear empirical distributions, was not sufficiently sensitive to the curvilinear empirical distributions examined here. These correlations have utility only as indicators of the strength of association between these two distributions across time and organization size. No other inferences were drawn because of the nature of the distributions.

C. THE KOLMOGOROV-SMIRNOV TWO SAMPLE EXACT TEST

The interpretation of these findings reinforced the comments concerning the utility of the p coefficient as discussed earlier in this chapter. The Kolmogorov-Smirnov test rejected the hypothesis that Mayhew's Harmonic Series predicted the observed rank-frequency distribution of roles at the .05 significance level for 70 percent of the years examined. It appears that for a young, small organization, Mayhew's Harmonic Series Model does not have utility as a predictor of a rank-frequency distribution of roles. Again, this appears to be because his model is based on data from a long established, reputedly "bureaucratic" sample.

The school district was comprised mostly of teachers and custodians in the early years of its life. Administrative and clerical positions, e.g., Principal, Vice-principal, Counsellor, Librarian, etc., were occupied on a part-time basis until fiscal year 1930. Up to fiscal year 1948 only one secretary was employed for the entire district. Thus,

there existed a large gap between $F(f_1)$ and f_2 in terms of the frequency values for these roles. The $F(f_1)$ role was always elementary school teachers; and its value was, generally, significantly larger than the value of f_2 during the early years.

As the school district bureaucratized, however, Mayhew's model gained utility. Several clerical, maintenance, and food services positions were created, and staffed in increasing numbers, eventually closing the gap with elementary school teachers. High school teachers, at all times broken down into several specialized roles, grew in number and were, generally, distributed about the lower one-third of the Harmonic Series curve.

As size increased across time, p increased at a decreasing rate until bureaucratization stabilized, then p decreased at a decreasing rate with further increases in size.

When the years examined were limited to those with 25 or more roles, in order to minimize the disturbance caused by small sample size and too few intervals, the null hypothesis was rejected for 14 of 23 years. The accept-reject pattern continued to be unclear at the .05 significance level. This mixed pattern reflected the erratic post World War II growth of the organization through the 1950's as the administrative overhead ratio to direct labor (i.e. teachers) alternated year by year. This erratic pattern stabilized by the 1960's, but the organization's size continued upward at increasing rates through fiscal year 1969.

Mayhew, _et al._, warned of problems in testing the Harmonic Series Model due to ambiguous definition and coding of occupational roles. The coding of the "elementary school teacher" role was initially uncertain. The investigator followed the subjective meaning employed by

school district personnel. That is, an elementary school teacher is not a role specialized by pupils' grade, but is qualified to teach any level, kindergarten through grade six. In addition, state certification criteria specify that a certified elementary teacher is qualified to teach kindergarten through grade six. Employment of a teacher in a particular pupil grade is a function of current teaching vacancies and teachers' preferences. The district Board minutes from fiscal year 1904 through 1962 show assignment flexibility in shifting elementary teachers among the levels kindergarten through sixth grade. In order to meet fluctuating elementary student loads, this was the organization policy adhered to by the Board of School Trustees and the elementary school Principals in all 68 years studied. Further specialization of this occupational category could not be considered. This coding resulted in "elementary school teacher" being the largest role across the entire sample of years.

Denzin (1970) has argued that, for meaningful discussions between different researchers to occur, the definitions of the objects under consideration must be consensual. The researcher must be able to balance his subjects perspective of the environment with his own. He must be able to accept the role of the "acting other" while simultaneously distinguishing his own scientific conceptions of reality. In this sample, while S (the number of employees in the organization) and r (the rank of the n^{th} occupational role according to decreasing values of f_i) increased and F decreased relative to r_n across time, there remained difference between $F(f_1)$ and f_2, to seriously challenge the utility of Mayhew's particular Harmonic Series as a description of the shape of organizations in general.

V. CONCLUSIONS

A. THEORETICAL IMPLICATIONS

In this study, the p coefficient was found to be unbounded and to vary inconsistently as a rate across time. The p coefficient was found to increase at a decreasing rate with increasing size as the organization bureaucratized and to decrease at a decreasing rate for further increases in size as the bureaucratization process stabilized.

The Kolmogorov-Smirnov Criterion was found to be more appropriate than the Chi-square and the Pearson correlation as a statistic testing goodness of fit. Nonetheless, it was unstable with small numbers of employees and small numbers of organization roles. Further, the Kolmogorov-Smirnov Criterion did not render a clear pattern relating Mayhew's Harmonic Series Model to this data. A visual impression, of plots of the expected against the actual rank-frequency distributions, revealed that this Harmonic Model had considerable predictive utility at large organization sizes and large numbers of roles. However, the Kolmogorov-Smirnov Criterion became increasingly sensitive to differences in sample points in this region of larger organization size. The Kolmogorov-Smirnov Criterion, while more appropriate than the Chi-square, was not a statistic which reliably tested the predictive power of the Harmonic Series Model.

B. A GENERALIZED VERSION OF THE HARMONIC SERIES MODEL

Mayhew, et. al., (1972) present two equations from which p may be derived. These are,

$$F = n^p \qquad (4)$$

and

$$\log f_i = a + (-p)(\log r_i). \qquad (5)$$

Equation (4) yields

$$p = \frac{\log F}{\log n}. \qquad (6)$$

The derivation of p from equation (5) is more involved. In order to avoid confusing terms while adhering closely to Mayhew's explanation, we define:

S = the size of the formal system, given by the number of employees;

$\hat{F}$ = the theoretical number of employees in the largest role according to the distribution of roles in the Harmonic Series, $\hat{f} = \hat{f}_1$;

F = the observed number of employees in the largest role;

$\hat{p}$ = the ratio of the force of unification to the force of diversification;

$\tilde{p}$ = p as defined in equation (6), the ratio of the force of unification to the force of diversification in the observed distribution of roles;

i = the rank of the i^{th} role;

$\hat{f}_i$ = the number of employees in the i^{th} occupational role according to the theoretical distribution of roles in the Harmonic Series;

f_i = the observed number of employees in the i^{th} occupational role;

n = the observed number of different occupational roles in the formal system; and,

$$h = \sum_{i=1}^{n} i^{-p}.$$

Following Mayhew (1972)

$$S=(\hat{F})(h), \tag{7}$$

and solving for S we have,

$$S=\hat{F}\sum_{i=1}^{n} i^{-\hat{p}}=\hat{F}\sum_{i=1}^{n}\frac{1}{i^{\hat{p}}}=\sum_{i=1}^{n}\frac{\hat{F}}{i^{\hat{p}}}=\sum_{i=1}^{n}\hat{\varsigma}_i \,. \tag{8}$$

We define,

$$\hat{\varsigma}_i=\frac{\hat{F}}{i^{\hat{p}}} \,. \tag{9}$$

If the relationship in equation (9) holds then,

$$\ln\hat{\varsigma}_i=\ln\hat{F}-\ln i^{\hat{p}} \tag{10}$$

so that,

$$\ln\hat{\varsigma}_i=\ln\hat{F}-\hat{p}\ln i \,, \tag{11}$$

which is equivalent to equation (5), with the exception that Naperian rather than common logarithms are employed. Therefore,

$$\hat{p}=\frac{\ln\hat{F}-\ln\hat{\varsigma}_i}{\ln i} \,. \tag{12}$$

Notice that equation (11) is of the form

$$\hat{y}_i=\hat{a}+\hat{b}X_i \,. \tag{13}$$

Thus, for the observed number of employees in the i^{th} occupational role we would expect

$$\ln f_i = (\ln \hat{F} - \hat{p} \ln i) + \varepsilon_i \tag{14}$$

where ε_i is the error term, or the unexplained residuals attributable to the difference between f_i and $\hat{f}_i$.

Solving for ε_i we obtain

$$\varepsilon_i = \ln f_i - (\ln \hat{F} - \hat{p} \ln i), \tag{15}$$

which, from equation (11), reduces to

$$\varepsilon_i = \ln f_i - \ln \hat{f}_i \tag{16}$$

The problem therefore, is to

$$\min S = \sum_{i=1}^{n} (\varepsilon_i)^2 = \sum_{i=1}^{n} (\ln f_i - \ln \hat{f}_i)^2 \tag{17}$$

in order to determine whether to accept or reject the hypothesis that the Harmonic Series predicts the observed rank-frequency distribution of roles. Our aim is to minimize the difference in the two distributions. Substituting equation (11) into equation (17), taking partial derivatives with respect to $\ln \hat{F}$ and then with respect to $\hat{p}$, and setting these equal to zero, we obtain,

$$\ln \hat{F} = \frac{1}{n} \sum_{i=1}^{n} \ln f_i + \hat{p} \frac{1}{n} \sum_{i=1}^{n} \ln i \tag{18}$$

(Suits, 1963).

Equation (18) reduces to,

$$\ln \hat{F} = \overline{\ln f_i} + \hat{p}\,\overline{\ln i} \quad . \tag{19}$$

From equations (18) and (19) the computational form for the solution to $\hat{p}$ is

$$\hat{p} = -\frac{\sum_{i=1}^{n} \ln f_i (\ln i) - \overline{\ln f_i} \sum_{i=1}^{n} \ln i}{\sum_{i=1}^{n} (\ln i)^2 - \overline{\ln i} \sum_{i=1}^{n} \ln i} \quad . \tag{20}$$

The assumption underlying the present analysis is that Mayhew, et al. (1972) developed p from equation (4). This would be theoretically and empirically desireable because the solution of equation (4) is less involved than the solution of equation (20). However, equation (4) defines the observed and expected distribution of roles as originating at F, where F and $\hat{F}$ have the same value. Defining p in this manner ties the observed distribution to the theoretical distribution through F, which may account for Mayhew having obtained a good fit with his Coast Guard data. In addition, equation (4) uses only the role with the largest number of people to compute p values. Equation (20) uses the values of all the roles in the observed distribution to compute the value of p. Hence, it is expected that equation (20) will approximate p more accurately than equation (4). The question remains as to whether the difference between the value of p computed by equation (20) and the value computed by equation (4) is statistically significant. This is one of several

problems to be addressed in the continuing analysis of the school district data.

An important caveat to the preceeding argument is the effect of ln $\hat{f}_i$ on ln i in equation (11). The sign of p•ln i results in ln i varying inversely with ln $\hat{f}_i$ as ln $\hat{f}_i$ is regressed on ln i. However, ln $\hat{f}_i$ also affects ln i inversely as the regression progresses, but not to the extent that ln i affects ln $\hat{f}_i$. Thus, the qualification to equation (20) is

$$E(\hat{p}) > p_{actual} \tag{21}$$

where $E(\hat{p})$ is the expected value of the theoretical distribution from equation (20). Determination of the equation that will yield the value of the above relationship will be attempted in future analyses of the school district data.

C. PRACTICAL IMPLICATIONS

If the interpretation of the results from these investigations indicate no significant difference from measures of organizational variables obtained using cross-sectional designs, longitudinal investigations will, at least, settle the controversy over the relative importance of time ordering of variables. If longitudinal results are significantly different from cross-sectional data, then more researchers should adopt longitudinal designs in future investigations. In either case, significant advances will have been made in contributing to the construction of a universal, formal theory of organizations.

APPENDIX A

Fiscal Year 1936

Position	Full-time	Part-time	Direct Labor
Elementary School Teacher	19		YES
District Superintendent	1		
Fiscal Agent - WPA		(1)	
WPA Agent		(1)	
Principal	1	(2)	
Vice-Principal		(2)	
Dean of Girls		(1)	
Secretary	1		
Librarian		(2)	
Nurse	1		
Attendance Officer		(1)	
Athletics Physician		(1)	
Janitor	2		
Assistant Janitor		(2)	
Gardener		(2)	
Nature Study Teacher	1		YES
Manual Training Teacher	1		YES
Physical Education Teacher	2	(1)	YES
Industrial Arts Teacher	1		YES
Commercial Department Head		(1)	
Commercial Teacher	3		YES
Foreign Language Teacher	1		YES
Social Studies Teacher	1		YES
English Teacher	2		YES
Math Teacher	1		YES
Science Teacher	1		YES
Art Teacher	1		YES
Band Teacher	1		YES
Voice Teacher	1		YES

APPENDIX B

Fiscal Year 1936

Summary

	Roles			Positions		
f	FT	PT	DIR	FT	PT	DIR
19	1		1	19		19
3	1		1	3		3
2	4	(5)	3	8	(10)	6
1	10	(7)	6	10	(7)	6
Totals	16	(12)	11	40	(17)	34

COMPUTER PROGRAM

FORTRAN Statements: Theoretical Harmonic Series Distribution

```
      DIMENSION T (100)
   99 READ (5,100,END=999)F,P
  100 FORMAT (F10.0)
      DO 1 N= 1,100
      T(N)= (N**P)**(-1)*F
    1 CONTINUE
      WRITE (6,101)F,P,T
  101 FORMAT ('1F=',E15.7,',P=',E15.7,//(E15.7))
      GO TO 99
  999 STOP
      END
```

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